

SPECIAL PROJECT FINAL REPORT

All the following mandatory information needs to be provided.

| | |
|--|---|
| Project Title: | Improvement of a convection-permitting Ensemble Prediction System over Italy |
| Computer Project Account: | SPITEPS |
| Start Year - End Year : | 2019 - 2021 |
| Principal Investigator(s) | Lucio Torrisi |
| Affiliation/Address: | COMET (Operational Center for Meteorology) - Italian Air Force Met. Service |
| Other Researchers (Name/Affiliation): | Francesca Marcucci (COMET) Marco Alemanno (COMET) Riccardo Scatamacchia (COMET) |

The following should cover the entire project duration.

Summary of project objectives

(10 lines max)

The goal of this study is to improve the convection permitting ensemble prediction system COSMO-IT EPS, over the Italian domain, based on the Ensemble Kalman Filter (EnKF) approach for the data assimilation component (estimation of the initial conditions) and the COSMO regional model (www.cosmo-model.org) for the prognostic one. The outputs of this system could then be used to generate new probabilistic products for aeronautical support, taking advantage also of the developed tools for fog and thunderstorm prediction developed in the framework of the EUMETNET SRNWP-EPS Project

Summary of problems encountered

(If you encountered any problems of a more technical nature, please describe them here.)

No real problem was encountered, neither technical nor conceptual.

Experience with the Special Project framework

(Please let us know about your experience with administrative aspects like the application procedure, progress reporting etc.)

We are familiar with the Special Project framework and we appreciated this way to proceed.

Summary of results

(This section should comprise up to 10 pages, reflecting the complexity and duration of the project, and can be replaced by a short summary plus an existing scientific report on the project.)

The high-resolution KENDA- LETKF analysis has been realized with a 40 members ensemble plus a deterministic member, having a 0.02° grid spacing (~ 2.2 km) and 65 vertical levels. First year of the project has been spent to evaluate the LETKF performance in comparison with the observation nudging scheme.

The same set of observations used in the operational data stream for the nudging analysis of the COSMO-IT model has been assimilated. The observational dataset comprises radiosonde ascents (RAOB), surface pressure observations from land and sea stations (SYNOP, SHIP, BUOY), manual and automatic aircraft observations and wind profilers. An a-posteriori perspective has been assumed as regards the treatment of random model error. We use a combination of additive and adaptively-varying multiplicative covariance inflation techniques. Model uncertainty representation through a stochastic physics scheme (Buizza et al, 1999; Palmer et al, 2009) has been also implemented in the prognostic model. Sea surface temperature perturbations derived from randomly selected, scaled consecutive analysis differences has been daily inserted together with stochastic soil moisture perturbations.

The EnKF-based assimilation cycle has proved to be of superior quality with respect to the nudging over of a past dataset (from 04 Nov 2017 to 22 Jan 2018) (fig.1,fig2) and it has therefore become operational.

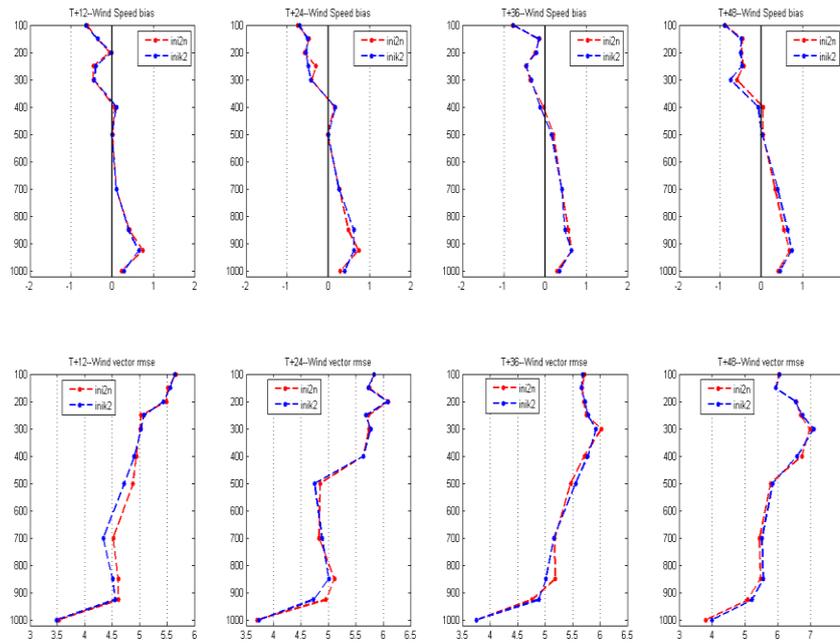


Fig.1 Upper level verification with respect to radiosondes observations (over Italy) of COSMO-IT (00UTC run) forecasts initialized by kenda-letkf (BLUE) and nudging (RED) assimilation. Top panels: wind speed bias for different forecast steps (from T+12 left to T+48 right). Bottom panels: wind vector rmse for different forecast steps (from T+12 left to T+48 right).

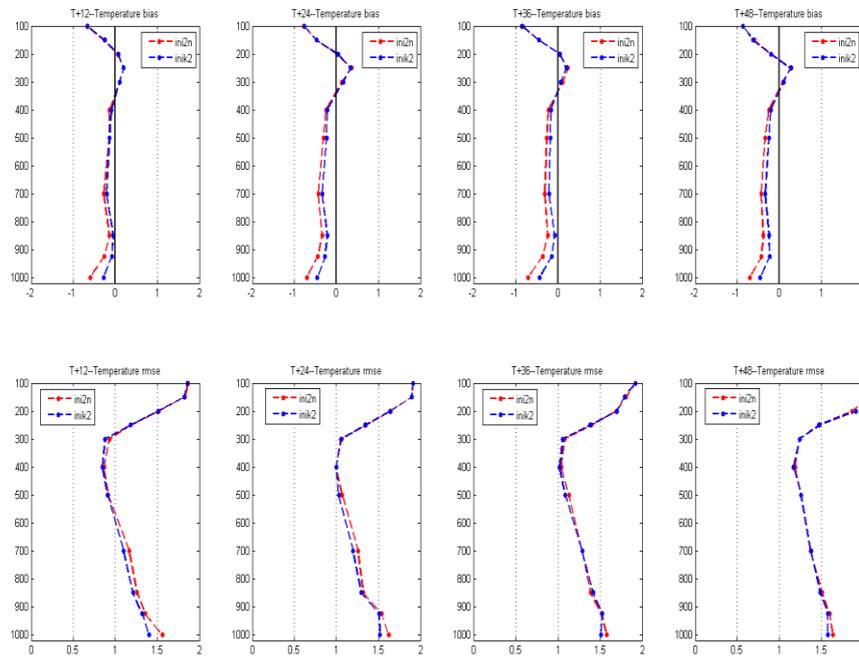


Fig.2 Upper level verification with respect to radiosondes observations (over Italy) of COSMO-IT (00UTC run) forecasts initialized by kenda-letkf (BLUE) and nudging (RED) assimilation. Top panels: Temperature bias for different forecast steps (from T+12 left to T+48 right). Bottom panels: Temperature rmse for different forecast steps (from T+12 left to T+48 right). Results are shown (fig.1, Fig.2) for a single test case of 27th august 2019.

A set of analysis members (20 over 40) has also been used to initialize the COSMO-IT EPS system. The COSMO model is integrated 20 times on the same domain of the COSMO-IT system with a grid spacing of 2.2 km, 576x701 grid points/layer and 65 vertical levels.

Deterministic and ensemble forecasts of the COSMO-IT/COSMO-IT EPS models have been used as input to the application package developed in the framework of the EUMETNET SRNWP-EPS project to forecast severe weather events (hereafter referred to as “TSdetect” code). The tool uses a combination of instability/moisture index and trigger conditions to define favourable conditions for shower/thunderstorm development. During the project two different configurations of the COSMO model has been compared in order to establish the better scheme for shallow convection (Tiedtke vs Bechthold) to be used in the COSMO-IT EPS system. The “Bechthold” configuration seems to allow a better for detection of thunderstorm with the TSdetect code, consequently the Bechthold scheme has been chosen for the operational configuration of COSMO-IT EPS as for the deterministic model COSMO-IT.

Results are shown (fig.1, Fig.2) for a single test case of 27th august 2019.

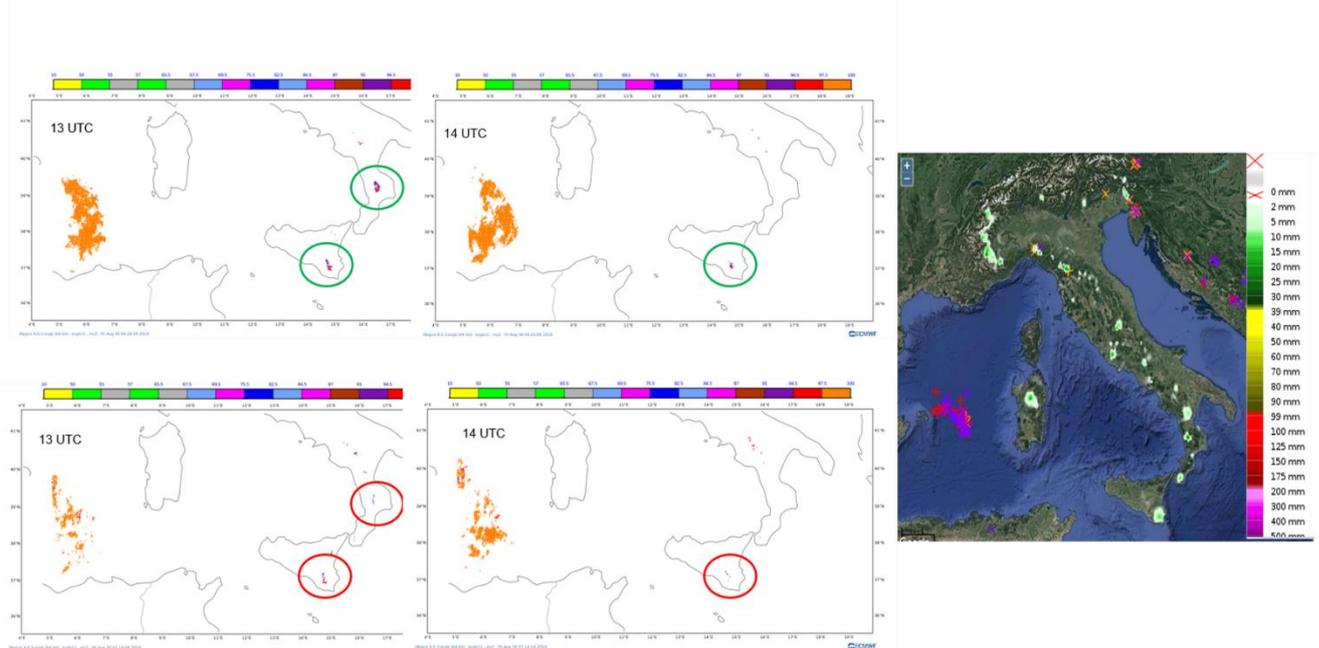


Fig.3: Outputs of the “TSdetect” tool applied to COSMO-IT EPS forecast (00UTC run of 27th august 2019), focus on convective precipitation over south Italy. Pictures show a synthetic output (most “probable phenomenon”) obtained combining forecasts from the 20 eps-members. Detected phenomena are represented with different colors: orange (thunderstorm with hail), red (thunderstorm), blue (shower). Left panel: Two different schemes for shallow convection parameterization are compared: “Beckthold” scheme (top) and “Tiedtke” scheme (bottom). Right picture: Radar and Lighting (red/purple crosses) maps for 6 hour cumulated precipitation (12- 18 UTC) of 27th august 2019.

Project resources has been also spent to evaluate the impact of different BCs for the LETKF cycle. In particular a comparison between COSMO-ME EPS BCs and ECMWF-EPS BCs has been performed over a long period (from December 2019 to may 2020). Performances have been evaluated with traditional forecast verification scores against synop observations and radiosonde data using the long deterministic run (initialized by the LETKF control member). Upper-air forecast verification scores against radiosonde data for the above cited period are shown in Fig.4, Fig.5 and Fig.6. For temperature, wind and humidity a substantial improvement was found throughout the whole column (reduction of both RMSE and BIAS for all forecast steps).

Given the evidence of a positive impact lateral Boundary conditions from the most recent IFS deterministic run perturbed using ECMWF EPS members became operational at the end of 2020. Moreover randomly selected ECMWF-EPS members have been also used as BC for the COSMO-IT EPS forecast system.

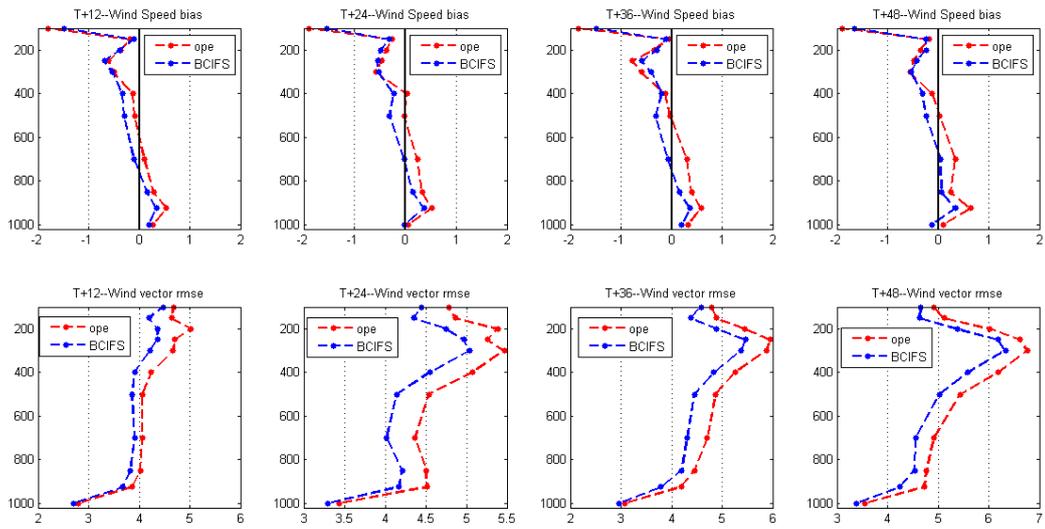


Fig.4 Wind speed mean Error (top) and wind vector Root Mean Square Error (bottom) vertical profiles for different forecast steps (from left to right: T+12h, T+24h, T+36h, T+48h), computed for COSMO-IT EPS forecast with BC from most recent ECMWF-EPS members (blue) and BC from COSMO-ME EPS members (red), using radiosonde observations in the period 1st December 2019 – 9th may 2020.

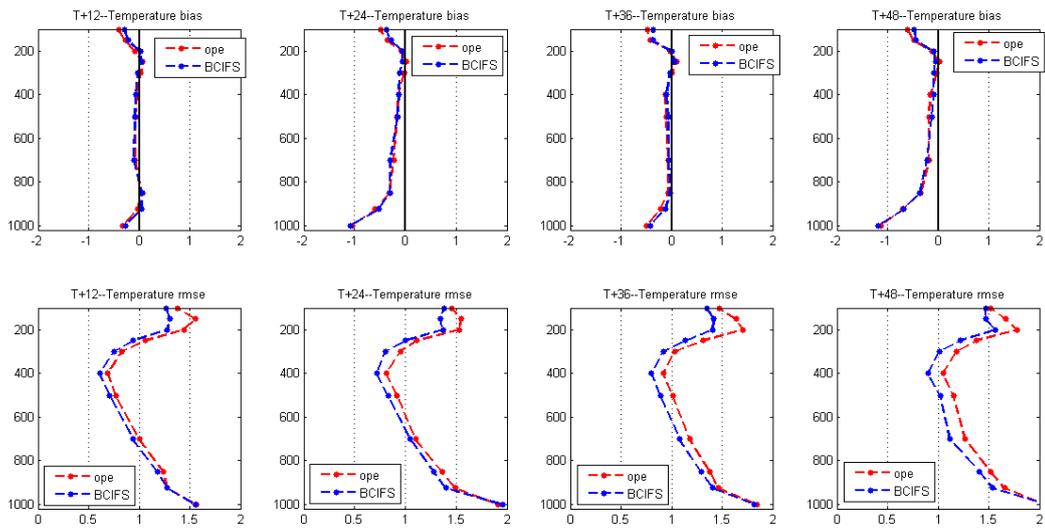


Fig.5 Mean Error (top) and Root Mean Square Error (bottom) vertical profiles of temperature for different forecast steps (from left to right: T+12h, T+24h, T+36h, T+48h), computed for COSMO-IT EPS forecast with BC from most recent ECMWF-EPS members (blue) and BC from COSMO-ME EPS members (red), using radiosonde observations in the period 1st December 2019 – 9th may 2020.

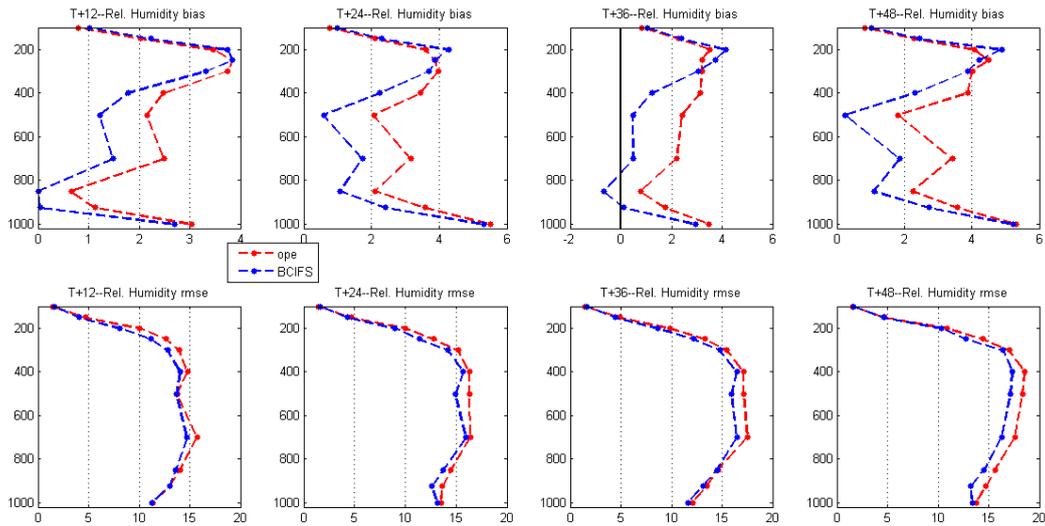


Fig.6 Mean Error (top) and Root Mean Square Error (bottom) vertical profiles of relative humidity for different forecast steps (from left to right: T+12h, T+24h, T+36h, T+48h), computed for COSMO-IT EPS forecast with BC from most recent ECMWF-EPS members (blue) and BC from COSMO-ME EPS members (red), using radiosonde observations in the period 1st December 2019 – 9th may 2020.

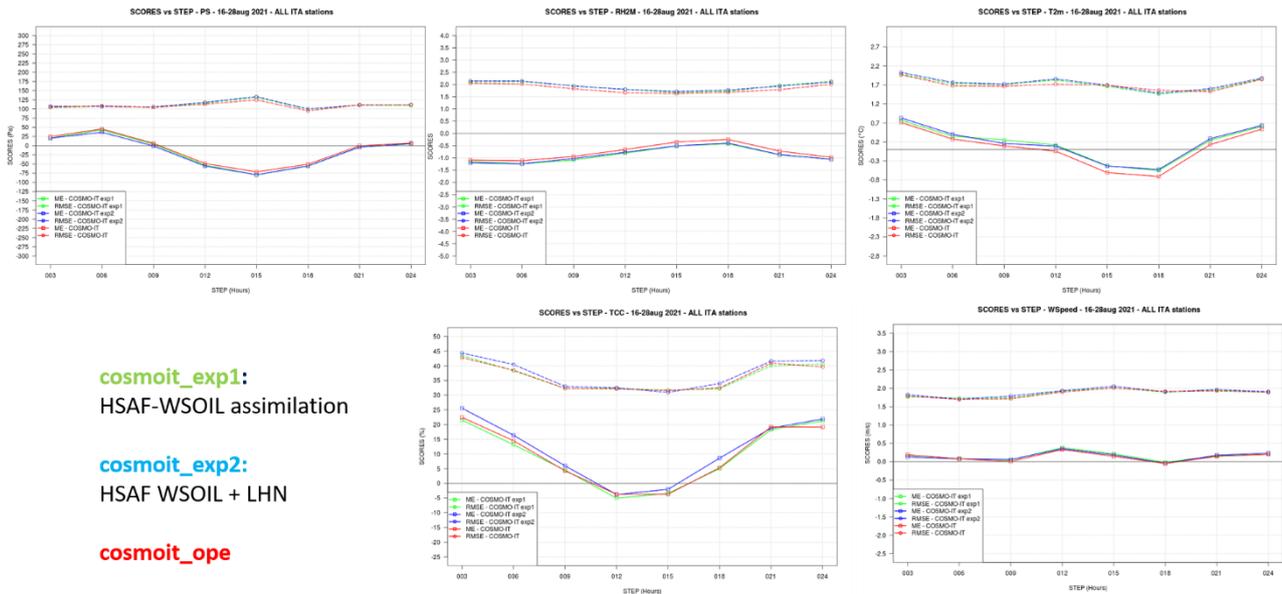
Last year developments

During the last period the introduction of latent heat nudging and the soil moisture assimilation has been investigated to achieve a further positive impact in the operational high-resolution NWP system. The assimilation of HSAF-ASCAT soil moisture observations has showed slight improvement in the 7km LETKF data assimilation cycle. The soil moisture observation operator has been then implemented in the high-resolution KENDA LETKF scheme and tested for a short period with the operational setup (1hour data assimilation window and COSMO-IT model).

Fig 7 and Fig 8 show the comparison of two different experiments, in the period 16-28 august 2021, with respect to the operational run.

First experiment “exp1” comprises operational configuration by adding HSAF-Soil moisture assimilation, while the second one (“exp2”) involves also latent heat nudging (LHN) together with soil moisture assimilation.

Given the low number of observations in the regional domain, the impact of soil moisture assimilation is almost negligible or slightly negative for surface parameters. The impact of LHN is also negligible for standard surface parameters, whilst it seems to overforecast precipitation in the first hours (Fig. 8) and, as observed through subjective verifications on few test cases, it seems to add areas of weak precipitation where there should be none.



cosmoit_exp1:
 HSAF-WSOIL assimilation
cosmoit_exp2:
 HSAF WSOIL + LHN
cosmoit_ope

Fig7. Mean Error and Root mean square error scores, as a function of forecast step, for (from top left to right, top to bottom) surface pressure, 2m relative humidity, 2m temperature, total cloud cover and 10m wind speed, computed for COSMO-IT (operational “red”, exp1 “green” and exp2 “blue”) using synop observations in the period 16-28 august 2021.

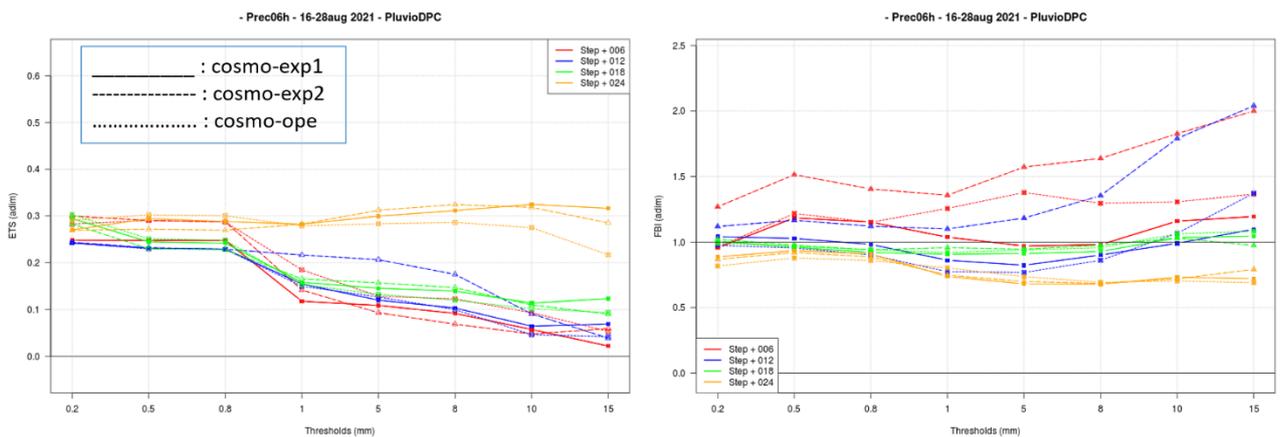


Fig8. ETS (left) and FBI (right) as a function of threshold (mm), for different forecast step, for 6hour cumulated precipitation computed for different configuration of COSMO-IT model (operational, “exp1” and “exp2”) using observations from the national hi-resolution rain gauge network (Civil Protection Department) in the period 16-28 august 2021.

Because the less than encouraging results, LHN and HSAF-soil moisture assimilation have been not yet included in the operational setup. Further investigation has been planned.

List of publications/reports from the project with complete references

None

Future plans

(Please let us know of any imminent plans regarding a continuation of this research activity, in particular if they are linked to another/new Special Project.)

In the next future assimilation of radar reflectivity volumes (in combination with LHN) and GPS slanted/ zenith total delay will be investigated in order to improve the analysis quality in the 1hour data assimilation cycle based on KENDA-LETKF algorithm and, consequently, the skill of the COSMO-IT EPS system.